**Version: 10 July 2016 Shane Delaney Onslow College Email:**

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| **Thin Ice webclips – annotations and possible activities (WORK IN PROGRESS)**  **For the clips see** [**www.thiniceclimate.org/free-resources**](http://www.thiniceclimate.org/free-resources) | | | |
| **Clip** | **Information/notes** | **Possible Activities/Relevant Science Capabilities/ Relevant NCEA standards** | **Other useful references and resources:** |
| **ANTARCTICA AND THE ICE CORE STORY – Ice Cores** | | | |
| A slice of Antarctic snow/ Digging a snow pit in Antarctica – Nancy Bertler | 2:40 mins  Intro to annual snow layers, capturing weather information – going back about 40years.  Measure chemistry – ions, trace elements. Clean gear, isotopes.  Measuring parameters in snow – chemistry, isotopes to make connection between weather/climate and the record in the snow – compare to cores for which there are no correlating meteorological observations to infer past weather/climate conditions |  |  |
| Analysing an Ice core – Nancy Bertler  + Dan Dixon | 5:54 \***audio** **tracking not good\***  Drilled almost 1000m. Clean suit. Find everything in ice – things breathed/evaporated from oceans/dust from continents. Core into melter – melts layer by layer back through time, water analysed in multiple ways as melted. pp quadrillion – 1s in 33Millio years! traces of nuclear bomb testing, dust as indicator of wind strength, properties of water/ice that indicate temp, or where air mass came from to precipitate the snow “taking DNA of atmosphere”  Bubbles in ice contain sample of real atmosphere through time – measure GHG in bubbles – indicate climate conditions at time snow fell.  Take records together from across continent – strong messages stand out – last 50-150years vastly diff from last 1000 or 10000y, e.g. H, O stable isotopes in water gives very good indication of T in continent – increased over last 50-150y.  CO2 at 280ppm over last 1000y now 386ppm in 2009  Methane sulphonate(?) produced by bacteria in sea ice – measure their productivity in ice cores, tells us sea ice has changed  Dust concentrations have increased linked to strength of winds (esp. westerly) around Antarctica; increasing steadily since ~1850, significantly since 1950 – on hemispheric scale! Large changes  Marine elements from ocean support this – westerly winds that circulate Antarctica have intensified and come closer. If A changes, fundamental consequences rest of planet:   * sea level * productivity of oceans * heat budget * storm tracks * wave patterns * things we don’t know yet   Past records suggest climate change doesn’t happen gradually – happens in big leaps, suddenly system changes mode very fast. We should be concerned that we are near such a fast mode change | This clip has a great number of examples of **proxy** indicators and making inferences from data    ***Gather and Interpret Data*** – Can you **link** the measurement (e.g. dust concentration, to the climatic condition  ***Using Evidence*** task to investigate **how the proxy indicators** give data about climate – could involve some research? POE task? Produce poster about one example of a proxy indicator.  ***Using Evidence*** - How do scientists use evidence to make **inferences**  ***Using Evidence*** and ***Critique Evidence*** – How do scientists combine different pieces of evidence to form coherent theory or make predictions  ***Using Evidence*** - How can measurements of current conditions be used to predict future events? |  |
| Shrinking Tropical Glaciers – Lonnie Thompson | 4:34  11% planet in polar region, but lots people work in this region (on climate science)  50% of planet in tropics – between 30N and 30S – energy comes in that drives climate (El Nino, monsoons).  Volcanic eruptions only have global impact if they occur in tropics – effects both hemispheres,  70% of people line in tropics- need to understand changes in climate these regions.  glaciers record information **about T** (through stable isotopes of O and H), **precipitation** (the net balance – tropics have distinct wet/dry seasons, dry seasons produce dust layers; measuring distance between dust layers gives precipitation history), record **forcings of climate** – tephra (incl. sulphates) from eruptions, GHG in bubbles, cosmogenic nuclides to tell how sun has varied through time. Need to understand both human and natural forcings to understand future. Ice probably best recorder – at high elevations in tropics, higher = colder = better archive. collected from tops of highest mountains – returning to many year after year we can see how quickly they are retreating – documented and mapped –began to be concerned that rate of ice loss is accelerating (Andes, Kilimanjaro, Himalayas, Rocky Mountains) globally, at low latitudes 100% of glaciers are retreating and, where there is data, accelerating | Advantages of studying glaciers in tropics |  |
| **ANTARCTICA AND THE ICE CORE STORY – A Polar Journey** | | | |
| Polar Plateau Part 1 – Getting there | 2.07  Blinded by light – sun reflecting off snow, pure white. Plane, a few tractors and sleds – that’s camp! plane takes off and feel alone |  |  |
| Polar Plateau Part 2 – Travelling across the ice | 4:50  Extreme conditions  Relying on yourself and your team  -25 to -30, more with wind chill – if touch metal with bare hands get instant frostbite  areas very ‘clean’ and far from human influence  1 safety vehicle looking for cracks/holes dangers – must stop within 20m  2 tractor, 7tonne sled with fuel and insulators, kitchen 4 people, 7ppl accoms, experiment gear, antennae  3 deep radar programme - can see all way through over 4000m of ice, layers within – right through to bedrock! – With person sitting inside!!!  4 sleds with fuel, food, trash boxes, ice cores and science equip, polar pooper  4-5 days to travel 235km, 4 to 5 stops on way to pole |  |  |
| Polar Plateau Part 2 – Coring for climate history | 3:55  Snow reflects chemistry of atmosphere at time it snowed – can go back 100s and 1000s of years of climate and see how both Antarctica and southern ocean have operated in past – how it operates naturally and compare with differences in how it operates today. Drills go 100-200m, taking back 200 to about 1000yrs. Every year snowfall preserved by subsequent years – drilling back further in time and see how chemistry of atmosphere has changed. Drill upwind of campsite to avoid contaminating drill area. Hollow drill bit captures core while drilling. Wind of 10-20kt. Drills 1m at a time – cores taken back for analyses.  If strong wind blows over ocean, sea salt spray whipped up and deposited on ice sheet; levels of sea salt in ice core changes in time – gives indication of wind strength changes.  Once A starts to change, fresh water comes out, raises sea level, changes ocean circulation, extent of sea ice, wind systems around this area – potential for triggering large changes in Southern Hemi AND around world.  Becoming much more certain about predictions for possible change in future | Sea spray deposits as proxy for wind strength over oceans – see activities with proxy indicators for “Analysing an Ice core – Nancy Bertler  + Dan Dixon” above |  |
| **ANTARCTICA AND THE ICE CORE STORY – Climate Information from Ice Cores** | | | |
| Ice Age Cycles, Temperature and CO2 – Tim Naish | 3:05  Milankovitch cycles as possible forcing mechanism to initiate g/h gas increases (T leads CO2). Contrasts with current scenario with humans driving ‘initial’ increase in T. “We’re the amplifier” | **L3 ESS** Analyse graphs showing link between Milankovitch cycles and glaciations.  Investigate positive feedbacks.  Investigate lead/lag relations between CO2 and temperature  **Science 1.16** *-* Investigate an astronomical or Earth science event *(Ice ages and Milankovitch?)*  **Science 1.15 -** Demonstrate understanding of the effects of astronomical cycles on planet Earth  ***Critique Evidence***: Investigate lead/lag relations between CO2 and temperature  Astronomical cycles extension – Investigate variations in Earth’s orbit | Other useful references: <http://www.azimuthproject.org/azimuth/show/Milankovitch+cycle>  <http://ossfoundation.us/projects/environment/global-warming/milankovitch-cycles>  <https://www.youtube.com/watch?v=dHozjOYHQdE> (video - really good) |
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| **Carbon Dioxide Today** | | | |
| Measuring atmospheric gases, Baring Head, Wellington, New Zealand | *complete details* | ***Interpret Representations:* SEE activity on interpreting CO2 level graphs**  Use as intro to activity on interpreting CO2 levels graph  Follow up with 2x clips: ‘Oceans and CO2’ and ‘Forests of the Ocean’  **Science 1.6 -** Investigate implications of the use of carbon compounds as fuels  **Science 1.14 -** Demonstrate understanding of carbon cycling  **Chemistry 1.3** - Demonstrate understanding of aspects of carbon chemistry  **Biology 1.3 -** Demonstrate understanding of biological ideas relating to micro-organisms | Science Learning Hub interactive Carbon Cycle: <http://sciencelearn.org.nz/Contexts/The-Ocean-in-Action/Sci-Media/Interactive/Carbon-cycle> |
| How CO2 traps the Earth’s warmth | 4:16  Using spectrometer – point telescope directly at sun to measure solar spectrum. Intensity vs wavelength graph. Without atmosphere, would expect smooth declining curve (like inverse), just due to heat from sun. But large chunks taken out, mostly due to water vapour (clouds absorb these wavelengths) – longer wavelengths = what we think of as heat. Curve rises – heat generated by earth’s atmosphere itself, absorbing heat from sun and then re-emitting it in all directions. CO2 dominates in these longer wavelengths of spectrum. Puff CO2 into beam of sun in front of spectrometer - big dip in intensity in spectrum area that we think of as ‘warmth’ (IR) – Carbon dioxide has absorbed this part of the spectrum. This is the part of the spectrum where the earth is re-emitting energy that it absorbed from the sun – CO2 is such a good greenhouse gas | **Y13 Physics**? spectrometer/year 9 waves and energy  **13ESS heat budget**; comparing incoming spectrum from sun (short wavelength) to outgoing radiation from Earth’s atmosphere and absorption of CO2 (plenty of images in internet) |  |
| **The Greenhouse Effect** | | | |
| How CO2 warms our climate - Myles Allen | All climate system energy ultimately comes from Sun. Sun radiates at visible wavelengths – atmosphere largely transparent to visible wavelengths, so passes through and warms the Earth’s surface (some reflected by clouds). Earth has to ‘get rid’ of energy – can’t have imbalance for long. Earth much cooler than Sun, so radiated the energy in ‘gentler’ longer wavelengths – infrared. You can feel IR radiation – cold night in winter (one of few conditions were you get radiation escaping from surface) – top of hand feels colder than bottom. Most conditions atmosphere is too ‘think’ for this IR radiation to escape. Atmosphere very ‘opaque to IR’ so other mechanisms used to emit heat energy – e.g. evaporation and cloud formation transferring energy vertically (forming clouds through condensation and releasing energy at higher altitude) and convective thermals.  At about 5000m altitude, energy can escape directly through to space. Increasing greenhouse gas concentration raises the altitude that this can occur at (“the mist rises”). At higher altitudes the atmosphere is cooler and so loses heat to space **less efficiently**; less energy is released to space, creating imbalance and Earth’s atmosphere warms up. | **Y9, 11SCI and 13ESS Modes of heat transfer** (especially how cloud formation moves heat energy vertically in 13ESS)  **ESS 2.7 -**  Physical Principles related to the Earth System  **Science 1.4** – Investigate implications of heat for everyday life  **Physics 1.5 -** Demonstrate understanding of aspects of heat  Too advanced for year 9 Energy topic, but could help to frame lessons around climate change |  |
| How CO2 warms the climate - Ray Pierrehumbert | Temperature (a measure of the energy content) vs. energy. Find rate of energy going in vs energy going out. Sunlight absorbed as source of energy; second piece was energy loss mechanism (Fourier) – because space is a vacuum, only way that planet can radiate (lose) energy is through electromagnetic radiation (‘light’). Rate of loss of energy through IR Radiation will determine planet’s temperature. The hotter a body is, the more rapidly it emits IR radiation (loses energy). Energy received from sun at approx. fixed rate. Temperature increases until out = in at some equilibrium temperature = ‘radiating temperature of the planet’. Earth’s radiating temp ≈ - 20°C, even though surface temperature is greater. Difference between two is accounted for by GHG. Adding GHG changes radiating altitude, but not necessarily the radiating temperature. Rate of increase in temp as go through atmosphere closer to earth is approximately fixed, but staring at higher alt, means higher T by time reach surface.  Temperature difference (approx. 6 °C per km) through the atmosphere caused largely by convection. Can surmise how far radiating height needs to be pushed to produce a 2°C warming at surface – e.g. 6°C warming requires increase of 1km – takes small increase in GHG levels to raise altitude by approx. 300m (producing 2°C warming) – climate very sensitive to these changes. | See above. |  |
| **Modern Global Warming** | | | |
| Taking the temperature - Myles Allen and Phil Jones | 6.07  Climate is ‘noisy’ – can’t draw conclusions from a single year, have to take trends over decades. Detective work – ‘tease apart’ different competing factors that might effect – what matters vs incidental. Global Temperature Record (began early 1980s) from land and oceans – combine records ad digitise (and including historical) – since 50s and 60s have records covering about 80% of surface area of the Earth (!!). Scott’s expeditions – temperature (3x daily?), wind strength + direction, amount of cloud. St Petersburg Russia, 1847.  To go further back requires proxy records – some on year to year and season by season records – trees, ice cores, corals in shallow tropical seas. Combined with historical written records (e.g. Mediaeval, including artwork) about weather, harvests. Not as good as instrumental data, but can be combined and try to assign numbers to earlier periods. Warmest century in last Millennium was 20th C and coldest was 17th C. Overall warming since late 19th C is about 0.8 degrees C, top 10 warmest years all from 1997 – 2008 (**update at end:** since 2008, planet has continued to warm with 2010 being 1st or 2nd warmest year on record), with exception of 1999.  Climate now changing faster than typical lifespan of a human being; climate will be significantly different when you die compared to when you were born.  Recording temperature in Antarctica - One degree change in mean temp at Scott Base over last 50 years. | More on proxy records (see “Analysing an Ice core – Nancy Bertler + Dan Dixon” above) | see animations of temperature anomalies over time  Global Analysis; state of the climate NOAA (great images)  <https://www.ncdc.noaa.gov/sotc/global/201413>  To produce up to date temp. anomaly data: <https://www.ncdc.noaa.gov/cag/time-series/global/globe/land/ytd/12/1880-2014?trend=true&trend_base=10&firsttrendyear=1880&lasttrendyear=2016>  Clouds information from NASA:  [https://www.**nasa**.gov/pdf/135642main\_balance\_trifold21.pdf](https://www.nasa.gov/pdf/135642main_balance_trifold21.pdf)  <http://nenes.eas.gatech.edu/Cloud/NASAClouds.pdf> |
| Factors Besides CO2 – Myles Allen and Wally Broeker | If we had no record of temperature, but we knew GHG were rising, physics principles would tell us that we would expect temperatures to rise.  Between 1940 and 1975 there was no increase in T on the Earth, although CO2 were going up ….?  As GHG levels were increasing, so were other products of industrialisation (largely sulphates from coal-fired power stations) – these act to generate bright clouds that **reflect** sunlight and keep planet cooler than otherwise (Clip includes animations of aerosol hotspots as detected by satellite).  Then, in the West, power stations started to being cleaned up (sulphates also produce acid rain), so greenhouse ‘warming signal’ started coming through unmasked, hence rapid warming since 1980.  If doubling of CO2 were the only thing that happened, it would raise temperature by 1.2, 1.3°C. Not too much concern on its own, but would also raise water vapour content by 7%, which would raise warming to about 3.5°C. Water vapour is a stronger GHG than CO2. But effects of clouds hard to predict – delicate balance between different roles of clouds in atmosphere. So while the question of whether GHG cause global warming is ‘scientifically uninteresting’ – “Of course they do”. How much we should expect the world to warm is less certain. | ***Interpret Representations***: Analyse Temperature Anomaly graphs (see image downloaded from NOAA – contains trend line and error bars  **ESS 2.7 -**  Physical Principles related to the Earth System  **13ESS** could compare temperature and precipitation anomaly images (see NOAA website)  **13ESS** effects of clouds on Earth’s heat budget (see NASA factsheets x2) |
| **THE CHANGING ARCTIC** | | | |
| Life in the Arctic – a Sami view | Sami people relate their experiences of changing climate in the Arctic | ***Critique Evidence*** - Could use as a comparison of qualitative and quantitative evidence and also relate to use of historical (pre-measurement) evidence/records |  |
| **The Southern Ocean** | | | |
| Heading out to Sea |  |  |  |
| On Station |  |  |  |
| Oceans and Climate |  |  |  |
| Thermohaline Circulation | 5:50 |  |  |
| Taking the Pulse |  |  |  |
| Oceans and CO2 (5:41) | Wave action, cold water and CO2 uptake, hydrated CO2 molecules (x3). Phytoplankton blooms in spring uptake of CO2. (Nansen bottle). Deep ocean (1.5km down) ~ 60x the CO2 in whole of atmosphere. Sediment collection from sea floor. Biological Pump. CO2 uptake may be reducing in Southern Ocean (due to warming? Circulation changing?) | Use to follow interpreting CO2 levels ***Interpret Representations*** activity  **Biology 1.3 -** Demonstrate understanding of biological ideas relating to micro-organisms  **Science 1.10 -** Investigate life processes and environmental factors that affect them  **Gather and Interpret Evidence**: use of specific equipment, fair testing  Junior Science photosynthesis | <https://www.skepticalscience.com/warming-co2-rise.htm> video |
| Forests of the Ocean (3:36) | Seawater from English Channel used to culture (?). additives and light in lab. Analyse how micro-algae respond to changing carbon in ocean. “Invisible forests of ocean” – in 1mL 10,000 – 1,000,000 cells. Massive scale, impact on C cycle more than forests! We don’t appreciate it, due to their size. Last 60M years, CO2 levels dropped dramatically – have existed – how have they adapted? Esp. access to CO2 for photosynthesis. How will they respond to rapid CO2 rise – **fast** change! Will they mediate change to environment? |  |
| Out of Our Comfort Zone – Lionel Carter, James Rae | 5 mins  Global warming in geological time is a natural event – ‘swings and roundabouts’ between ice ages and warmer interglacial periods. Phytoplankton in water make 2 compounds and produce different amounts of each based on temperature – nice correlation with temperature; have worked out that sea surface temperature of Southern Ocean about 4 degrees cooler in last ice age. Drilling into seabed, 4500m below, right in the path of the Antarctic Circumpolar Current (it is one reason why Antarctica is cold). Cores are a ‘time capsule’ of how the current system operates; switched on/off/on/off – changing quite dramatically. Some core records back to 33Mya, we see onset of major current system. On natural, long time scale, the ocean has often in the past been what **drives** atmospheric CO2 concentrations and consequential climate changes. Humans have turned that natural cycle on its head by adding CO2 to the atmosphere – we’ll now watch how that interacts with the ocean. Big swings in CO2 in the past between approx. 300 – 120ppm. At the moment we’re 387ppm and we’re way out of our comfort zone. The climate changes in the past general come with mass extinction events and massive loss of biodiversity. The concern for us is that that massive loss of life could be our own. Looking at timing of cold/warm periods, the very high frequency events that occur quite rapidly tend (in the past) to lead from the Southern Hemisphere, Northern Hemisphere responds a little slower. What seeing now is quite unusual – forced from the Northern Hemisphere, heating up far more rapidly than Southern Hemisphere – so we have seen a change in the natural timing of these climatic shifts. Rapid changes in CO2 and environmental changes when approx. 40% of world’s population lives within 100km of the coast, those sorts of things staring to bite home. Global warming has strong human imprint. Understanding where the samples come from is important for scientists – otherwise miss the subtleties. | **L3ESS – ocean currents**  **investigate compounds** produced by plankton and howthese can be used as indicators (as well as why the production changes with T)  **ESS 2.7 -**  Physical Principles related to the Earth System |  |
| **CLIMATE MODELS** | | | |
| What past climates say about CO2 and warming.- Matt Huber | 8:44  50Mya planet was much warmer than today. Polar regions/high latitudes were ice-free, not below zero in winter. Large forests North Greenland, crocodiles North Pole, fossils of tortoises and subtropical planets – subtropical swamp environments at warmest periods of Eocene – more like coastal Florida. 30-60 deg. latitude, planet was easily 10 degrees warmer than today, significantly wetter. Best explanation for previous climate is CO2. How do we **know** what CO­2 was? By analysing bubbles in ice cores we can measure back 100s of thousands of years. To go further back, need entirely different approaches – a variety of ‘paleo-proxies’ for atmospheric CO2.   * density of stomata on fossil leaf – sensitive indicators. Compare to leaves living in the last 100 years. Limitation – leaves become less sensitive to CO2 concentration when there is high conc; above about 2x 560ppm then method finds hard to distinguish between fairly high and very high CO2. * alkanone (?)- based approach – diffusion of CO2 across cell membranes of plankton in oceans – we can model process at fine scale (individual cell). By analysing sediment from deep sea cores, biochemists. Strong indicator for records prior to 35Mya * boron technique – mineral (nahcolite) that only forms under high CO2 conditions – known to have formed 50Mya but not after that   CO2 was significantly higher; 3 or 4x (perhaps up to 8x) present day concentrations 55-50Mya 9early Eocene) then diminished around 35Mya, when Antarctic glaciation started. Dropped to about 2x current day concentration. Continues to drop to about pre-industrial conc. (280ppm). These previous perturbations were natural, now we are ‘turning the knob’.  CO2 today is higher than at any point in last 20My as far as we know. Over next 100 years we will be pushing levels up to those not seen since 45-50Mya, when there was no ice at poles and crocodiles along North Coast of Greenland.  Natural carbon cycle: inputs from volcanism, removed from system via weathering of continental sediments. Good theoretical models that suggest system was ‘skewed’ towards having more CO2 in atmosphere. Changes in tectonics, volcanism and amount of sea floor and changes of weathering rates on land due to alterations in plants on Earth’s circle from 50-20Mya pushed system into state with less CO2 in atmosphere. | **13ESS – *Using Evidence*/Investigating** how we know about previous CO2 levels. Detailed, but good example of interdisciplinary nature of paleoclimate research.  Suggests geological influences e.g. weathering of sediment and tectonics, but doesn’t elaborate on **how** these influence the carbon cycle. |  |
| **PAST CLIMATES** | | | |
| Geological record of past warm climates |  |  |  |
| The ANDRILL operation |  |  |  |
| View a freshly drilled core |  |  |  |
| Past warm periods and ice sheet melt |  |  |  |
| **THE FUTURE** | | | |
| Life in coastal Antarctica |  |  |  |
| Views on business-as-usual |  |  |  |
| Implications from rising CO2 levels – Stefan Rahmstorf | 6:09 |  |  |
| View on temperature rise – Malte Meinshausen |  |  |  |
| Trapping and Storing CO2 – Martin Blunt and Daniel Koseli | 6:13 – see bottom – The Role of Science |  |  |
| **CLIMATE NEGOTIATIONS** | | | |
| Climate Change as seen by UN negotiators and scientists inside the IPCC |  |  |  |
| **PERSONAL REFLECTIONS** | | | |
| Changing attitudes over the last 100 years – Sir Lloyd Geering |  |  |  |
| A warming planet and the legacy issues – Myles Allen | 4:14 |  |  |
| Being a scientist – personal thoughts |  |  |  |

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